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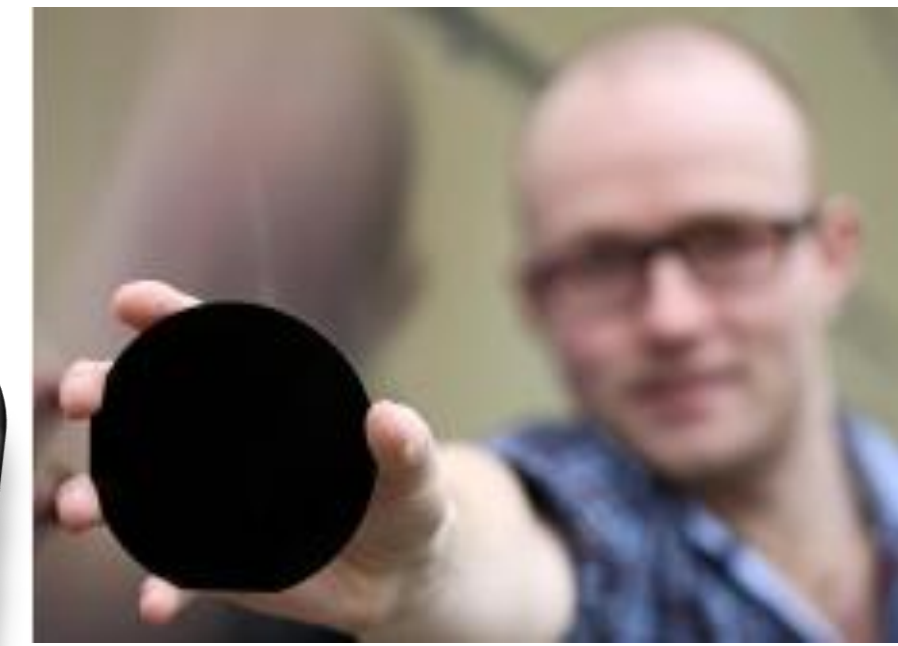
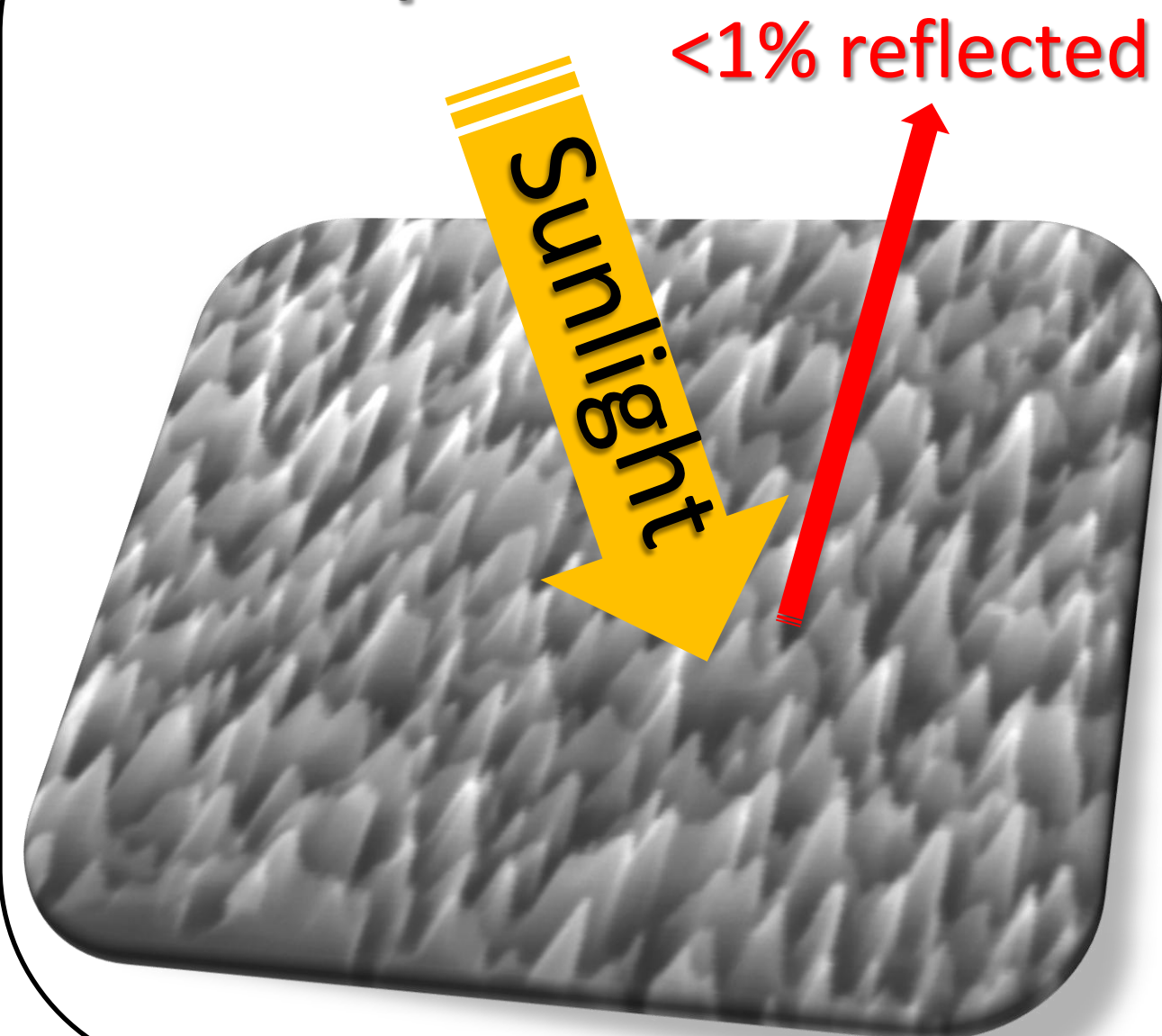


# Plasma etching on large-area mono-, multi- and quasi-mono crystalline silicon

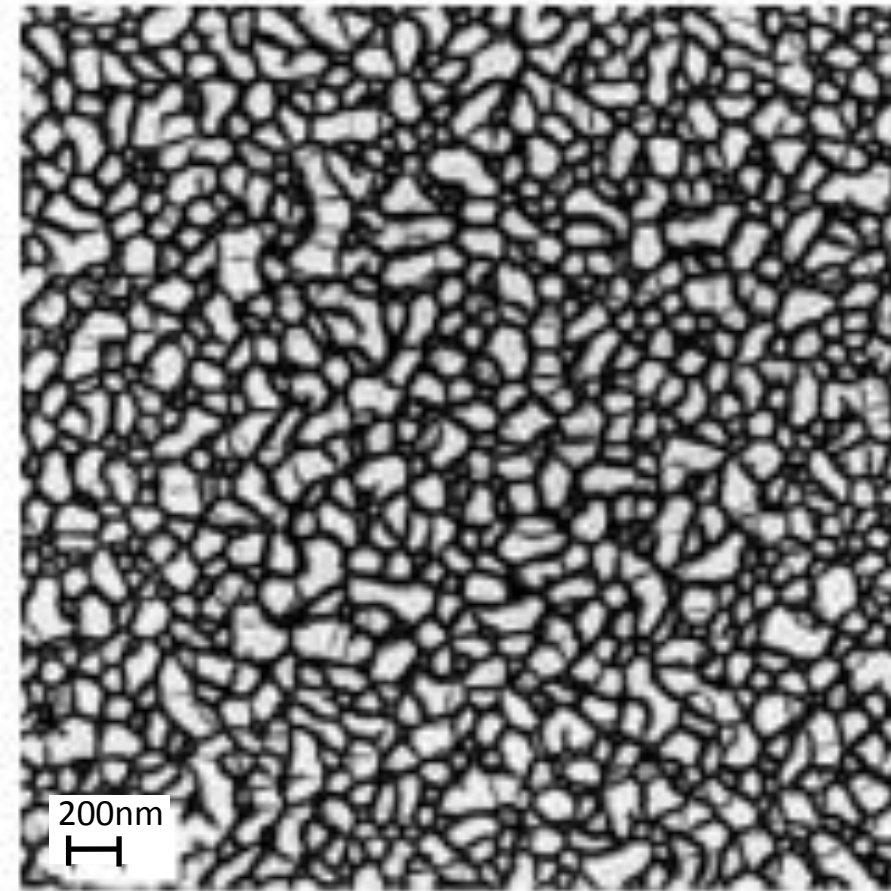
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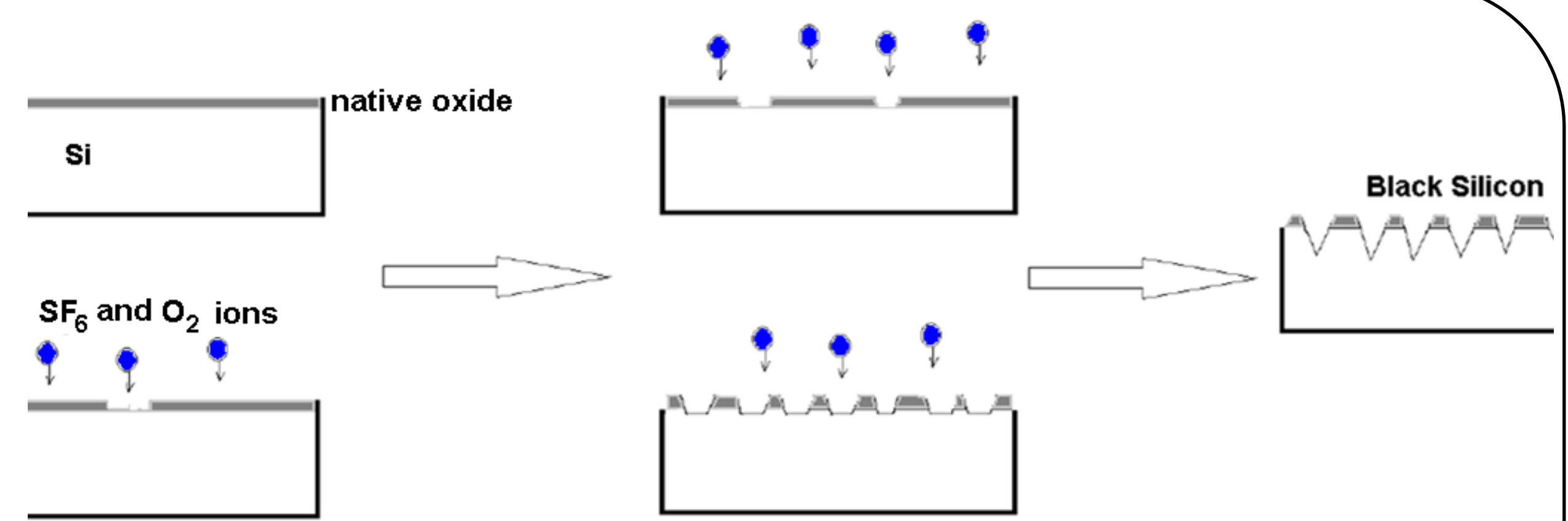
## Concept



Plasma-etched "Black Silicon" nanostructures significantly reduce the reflectance of sunlight

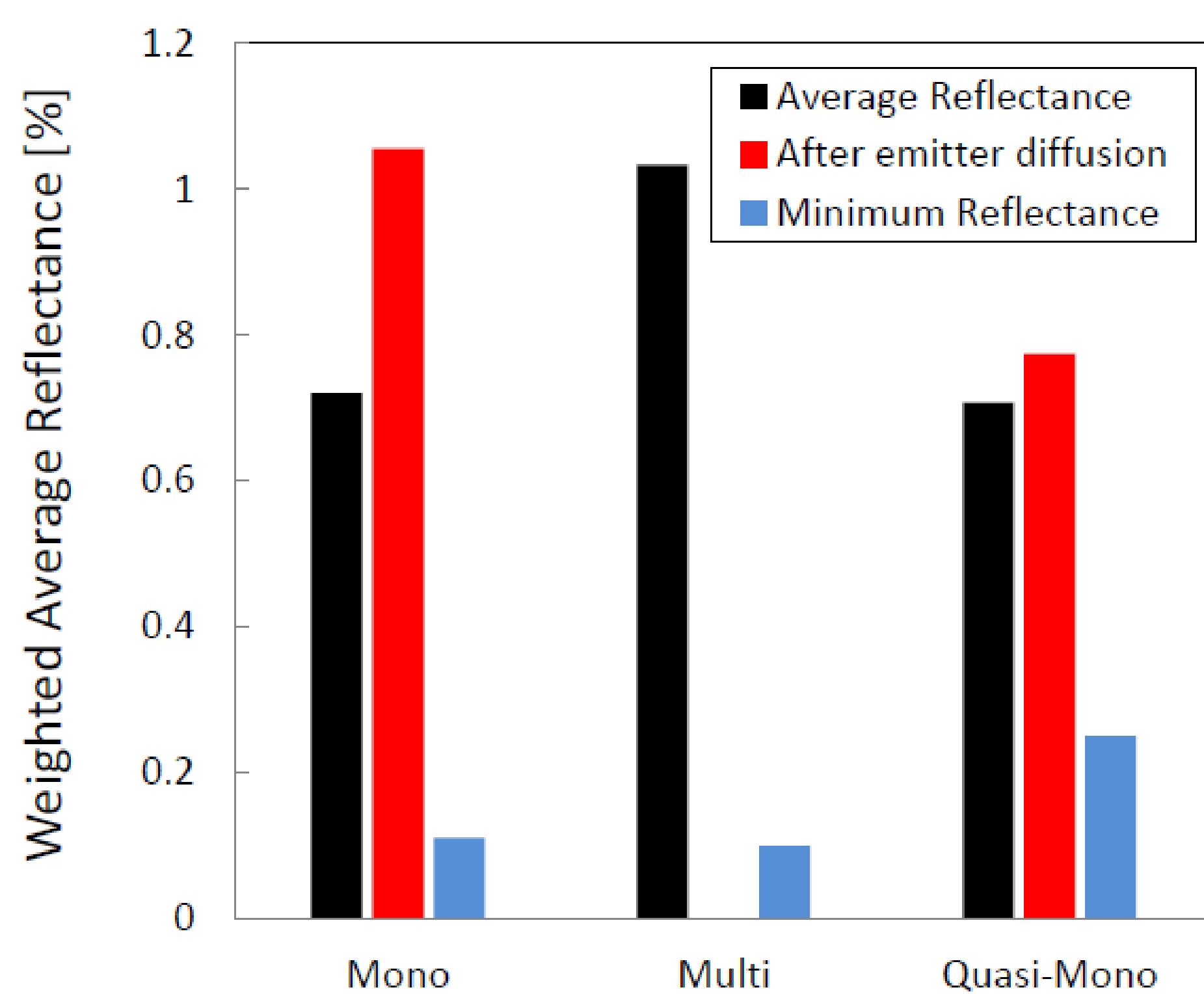


SEM-image (top-view) of the RIE-textured, nanostructured Si surface.



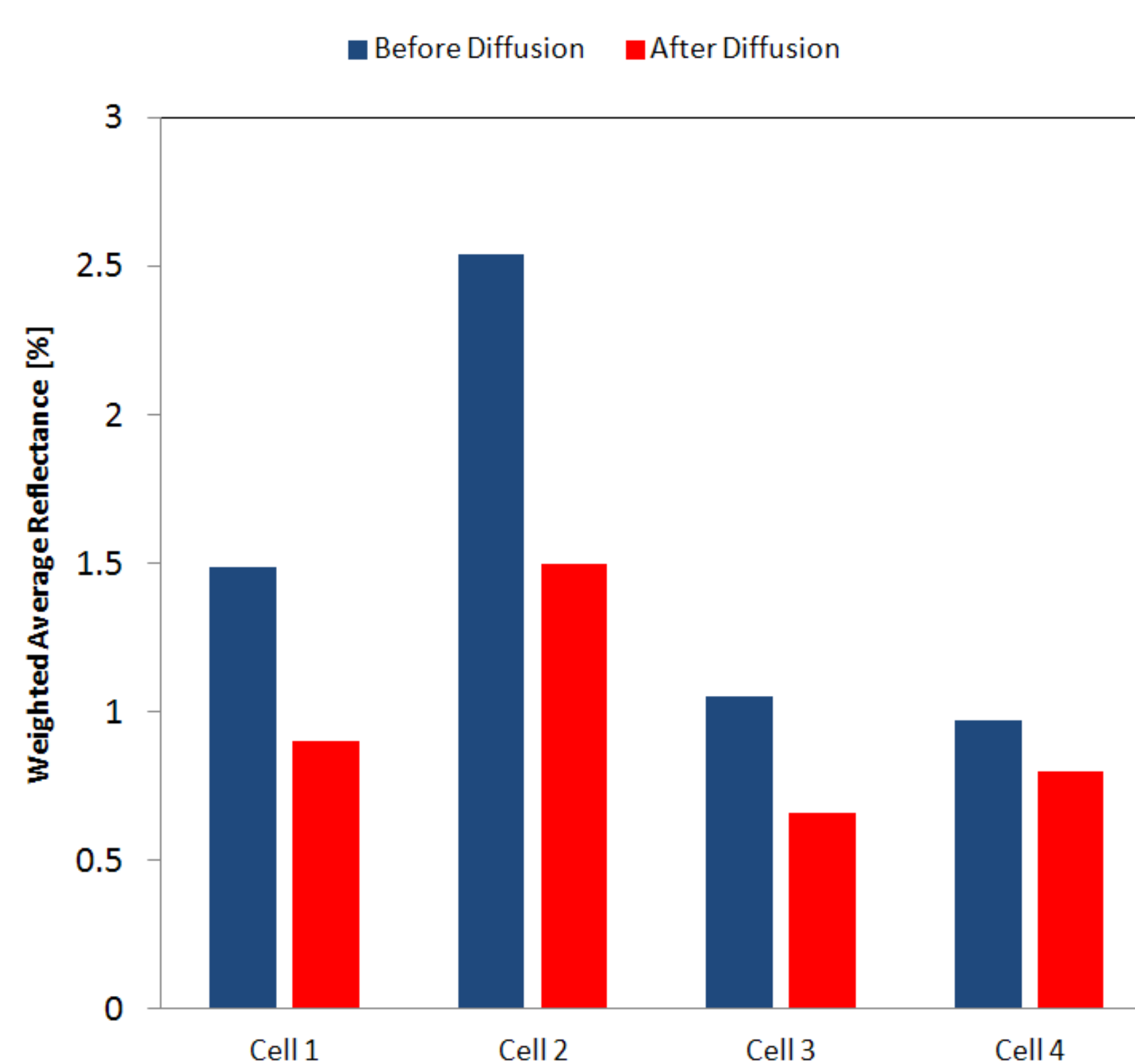
The nanostructures are fabricated by reactive ion etching, in which  $\text{SF}_6$  and  $\text{O}_2$  ions etch and auto-passivate the surface simultaneously. This creates a maskless etching of nanostructures at appropriate process conditions.

## Below 1% reflectance for different industrial types of Si:



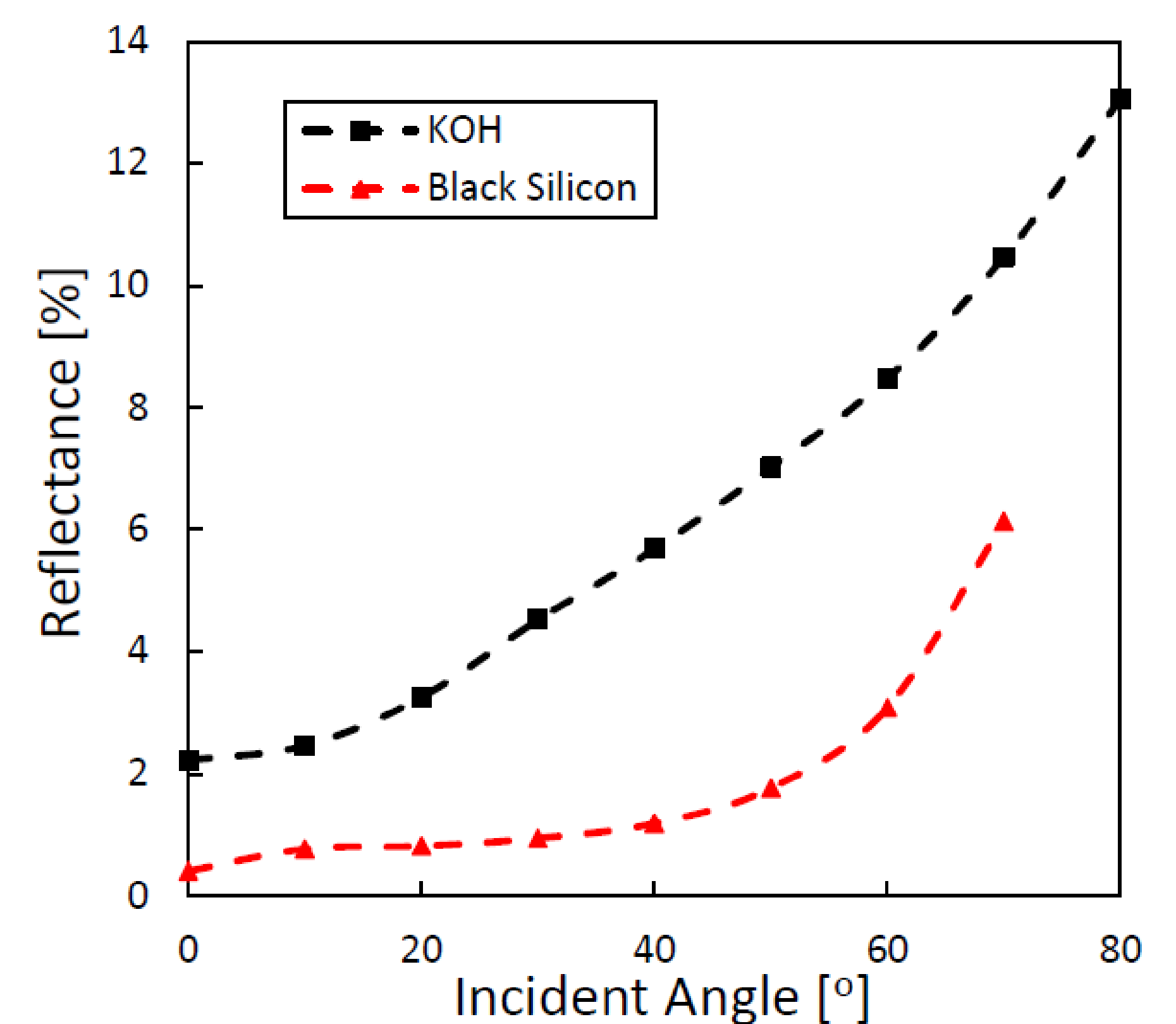
Weighted (AM1.5) average reflectance before and after emitter diffusion as well as the minimum reflectance of mono-, multi- and quasi-mono Si surfaces, respectively.

## $\text{POCl}_3$ Emitter Diffusion



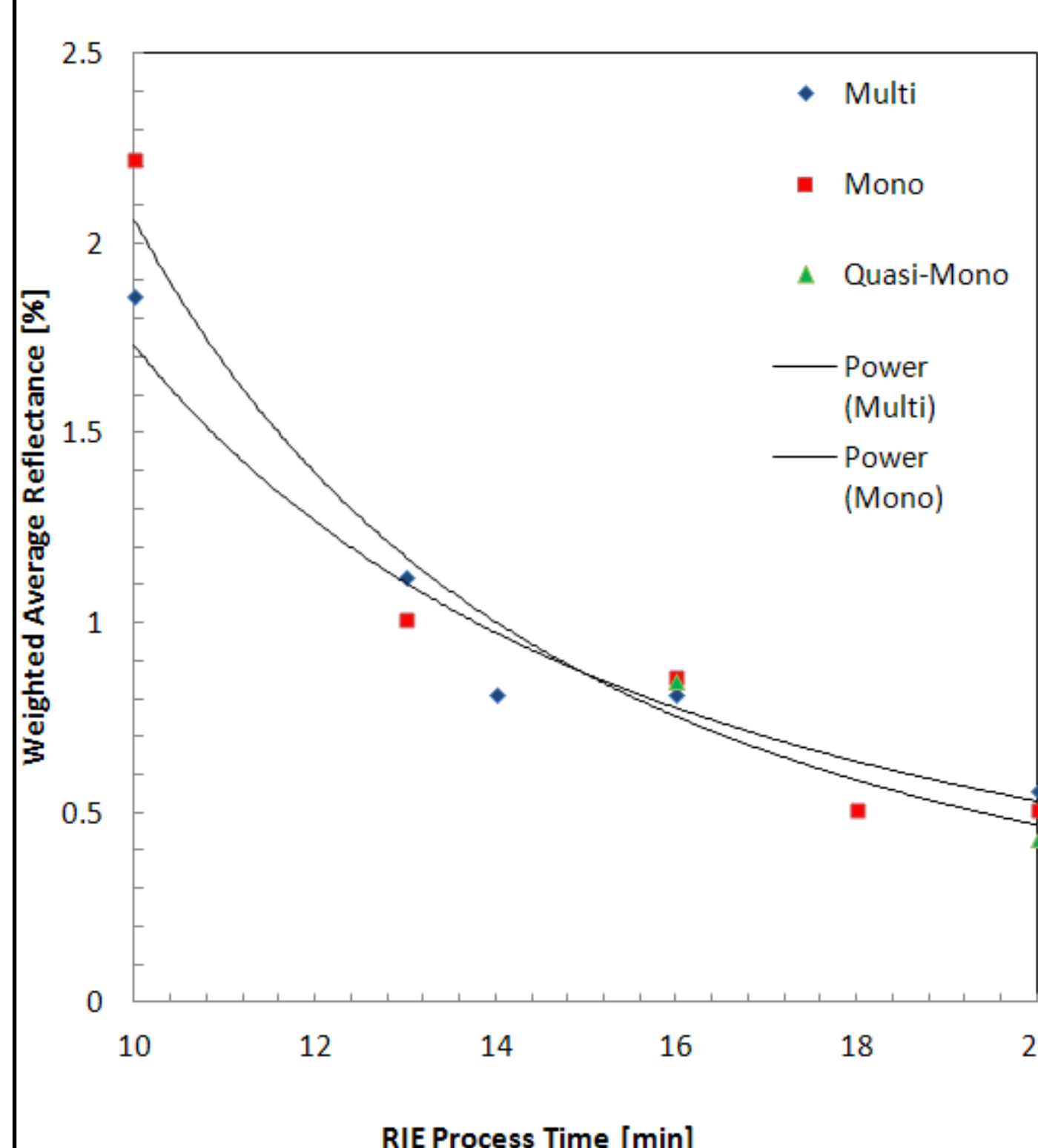
Weighted (AM1.5) average reflectance before and after emitter diffusion ( $150 \Omega/\text{sq.}$ ) for mono-crystalline Si with slightly different nanostructure texturing.

## Varying incident angle



Weighted average reflectance as function of incident angle for a KOH-textured (squares) and RIE-textured (triangles) mono-cr Si substrates.

## Etching time



Reflectance as function of RIE process time for mono-, multi- and quasi-mono crystalline Si, respectively. All other parameters than time were fixed. The general trend suggests that the reflectance decreases with  $t^{-2}$ .

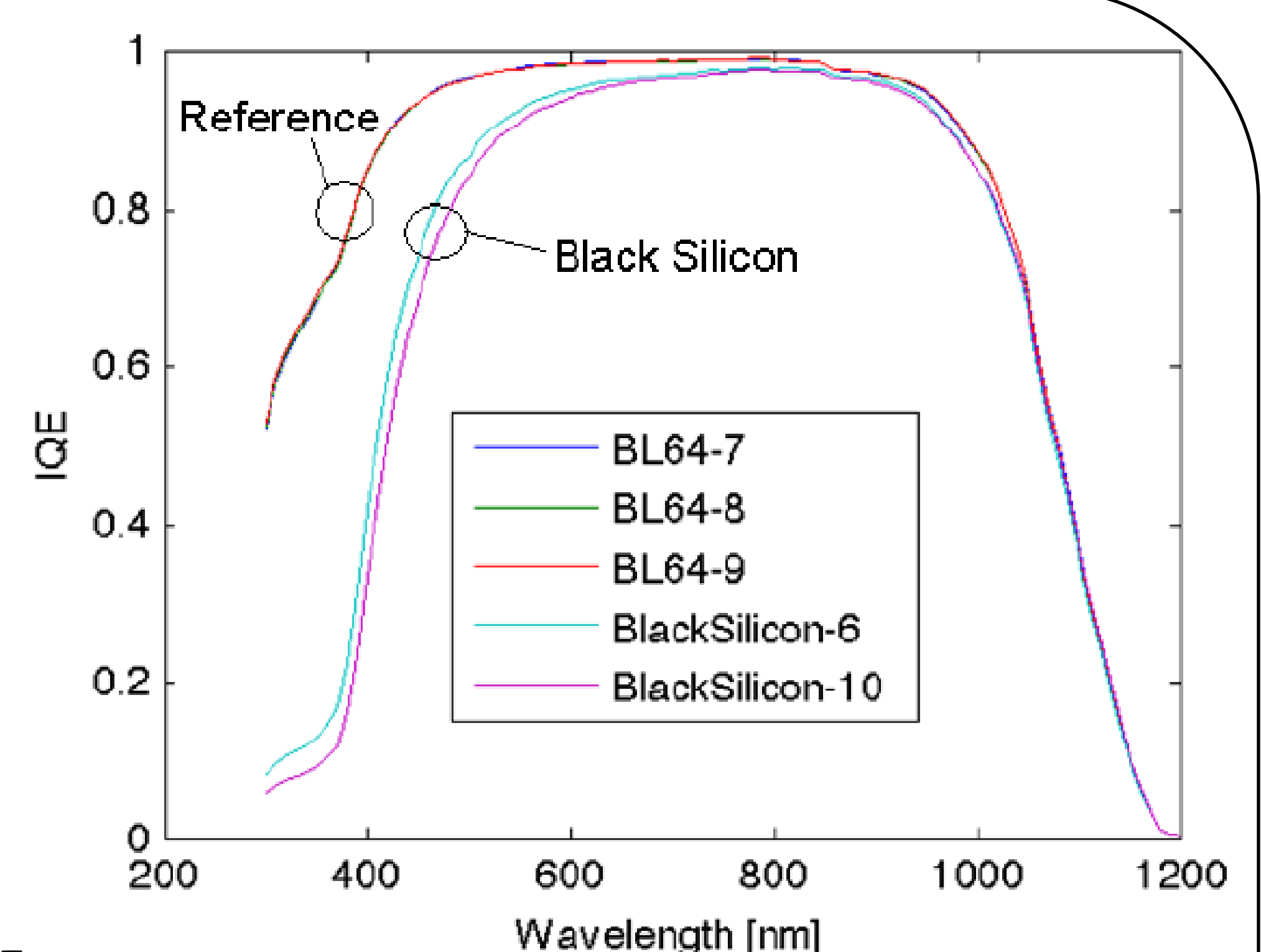
## Electrical Results:

	Total Carrier Loss	Emitter recombination
KOH	1.385 $\text{mA}/\text{cm}^2$	0.761 $\text{mA}/\text{cm}^2$
RIE	4.163 $\text{mA}/\text{cm}^2$	3.322 $\text{mA}/\text{cm}^2$

Calculated total carrier loss and carrier loss due to emitter recombination for the KOH- and RIE-textured cell.

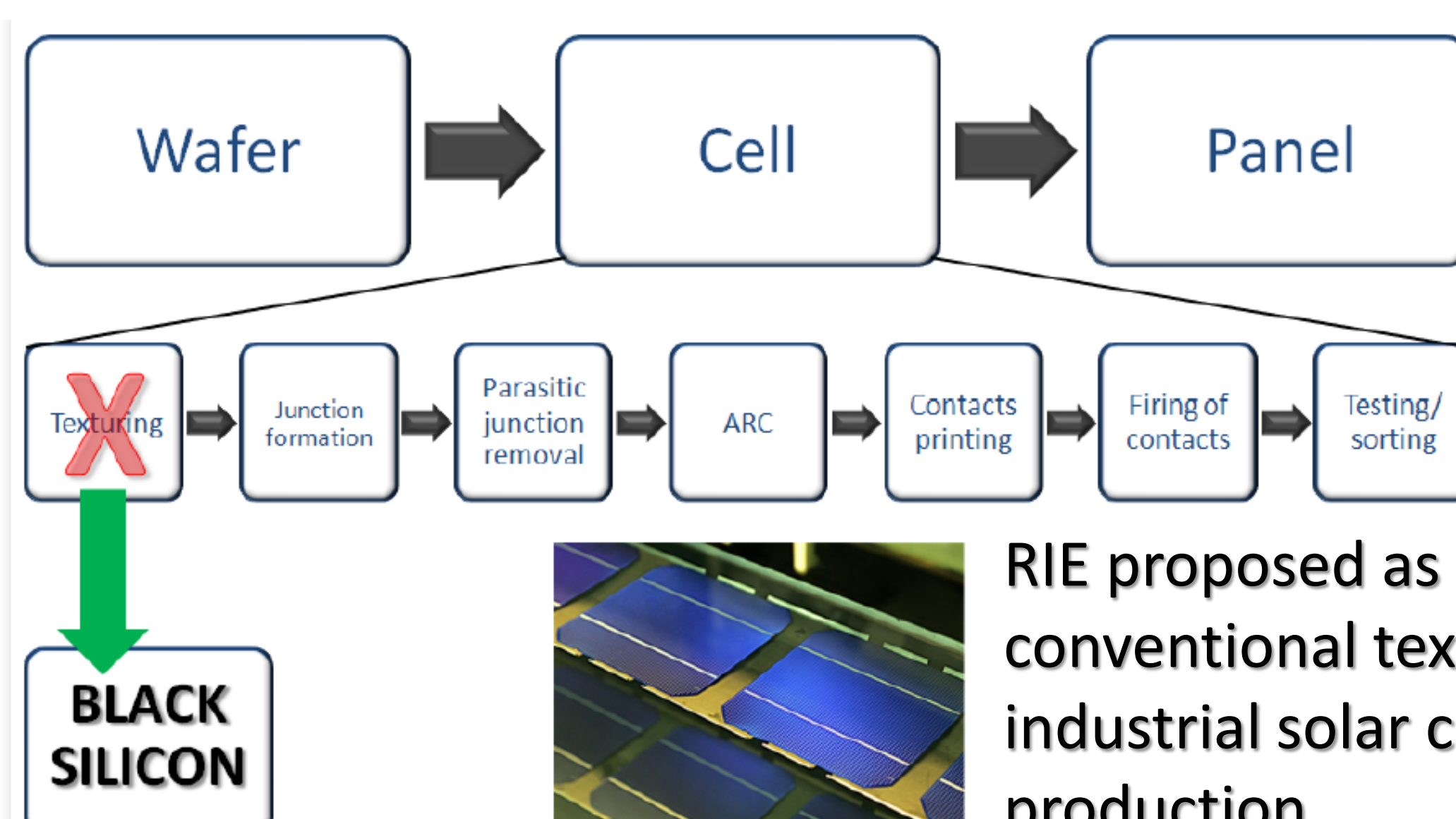
	PCE [%]	$J_{sc}$ [ $\text{mA}/\text{cm}^2$ ]	$V_{oc}$ [V]	FF	$R_{av}$ [%]
KOH	17.6	36.8	0.62	77.8	2-3
RIE, type 1	15.7	35.3	0.61	72.8	2.85
RIE, type 2	16.5	35.2	0.61	77.7	2.20

PV performance results including power conversion efficiency, PCE, short-circuit current,  $J_{sc}$ , open-circuit voltage,  $V_{oc}$ , fill factor, FF and weighted average reflectance after emitter diffusion,  $R_{av}$  of the RIE- and KOH-textured cells.

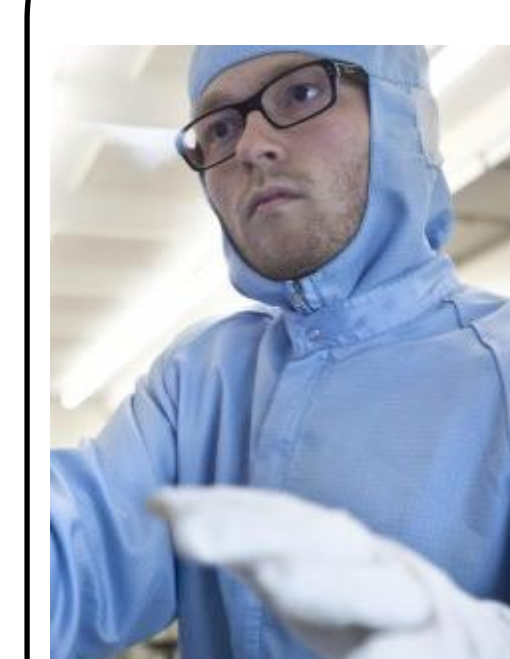


Internal Quantum Efficiency of two different black Si cells and three KOH-textured reference cells. Loss in short-wavelength IQE indicates surface recombination.

## Proposed Industrial Application:



RIE proposed as alternative to conventional texturing step in industrial solar cell production



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